Beyond Words

John L. Barth
American Printing House for the Blind
Louisville, Kentucky

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To the extent that it is possible, blind persons should have access to the same information as sighted persons. While tactile and auditory verbal materials have traditionally received the most attention in reducing the information barrier, another useful means of communication, graphic displays, has only recently begun to be recognized for its potential. Graphic displays in the form of maps, graphs, diagrams, and charts have the capability to convey certain types of information that cannot be easily or efficiently presented in verbal form. There simply does not seem to be a more effective vehicle for coding such information as the spatial relationships of the components of a map, the schematic representation of an object or objects in a diagram, or the relationships between variables in a graph. Failure to provide access to this wealth of information will place any individual, regardless of visual status, at a distinct disadvantage.

Availability of Readable Displays

Access is not a simple matter. Not only must the desired display be available in tangible form, but it also must be readable. Readability is dependent on the tactual clarity or legibility of the symbols used and on the way the display is designed. Strides have been made in these areas. While the bulk of tangible displays continue to be produced by such organizations as the American Printing House for the Blind (APH), Howe

Press, and the Raised Line Drawing Units of Recording for the Blind, availability has been enhanced significantly in recent years by do-it-yourself tangible graphics kits. In particular, the Tactile Graphics Kit (APH) and the Raised Map Making Kit (Blind Mobility Research Unit, Nottingham, England) have made it possible for any interested person to produce a variety of displays, each tailored to the needs of a particular individual in a particular situation. (These kits, incidentally, use graphic symbols that have been field-tested with blind persons to verify their legibility). Media centers, residential schools, teachers, mobility instructors, and parents have acquired these kits. A growing interest in making tangible displays available to blind persons is indicated by the fact that approximately 600 Tactile Graphics Kits have been sold in just the last 3 years. Because individual needs are so varied (mobility maps being a prime example), it is imperative that more people become involved in the display construction process.

These involvements, however, entail their own potential problems, particularly in the area of display design. The mere transliteration of a visual image into its tactile facsimile will often result in a confusing and unreadable display. The blind do not have an uncanny ability to "see" with their fingertips. The tactual system is much less adept than the visual system at processing graphic imformation and this limitation must be kept in mind when designing a tactile display. Although far from complete, research and practical experience in this area have given us some guidelines to go by. Information is available on such aspects of display design as optimal spacing between symbols, how to intersect lines, types of symbols to use in specific applications, symbols embedded in areal patterns, labeling, north indicators, minimum line lengths, and overall display size. Detailed information on these and other aspects of display design can be found in the _Tactile Graphics Guidebook_ (published by APH), in Billie Louise Bentzen's chapter in _Foundations of Orientation and Mobility_ (published by the American Foundation for the Blind), in _Guidelines for Mathematical Diagrams_ (published by the National Braille Association), and in the final two chapters of _Tactual Perception: A Sourcebook_ (published by Cambridge University Press). In general, when designing a tangible display, particular attention should be given to two factors that most often undermine a display's readability: complexity and clutter. Consider the purpose behind each display being constructed and present only the information that is necessary to convey it. Nonessential or confusing details should be eliminated. Avoid using too many symbols in a display, packing too many in a limited area, or placing similar or noncontrasting symbols adjacent to one another. In my opinion it is better to present too little rather than too much information in a single display. Extracting the information from a tangible graphic is not an easy task for most people. Clutter and complexity in a display complicate this task immensely.

Training

Designing readable tactile displays and making them available to blind persons does not, however, completely solve the access problem. In a larger sense, access is not realized until the information represented in a display is transmitted to the brain of the user and processed. Attaining this assumes the existence of a number of tactual-motor skills and a good deal of conceptual knowledge. These skills and concepts are not innate, but they are learnable; and that implies the need for training. Without proper training, access is severely limited. I emphasize this because it has been my experience that few blind students are given the most rudimentary training in how to interpret tangible graphic displays. Two of the major reasons for this state of affairs are, I think, the failure to reach practitioners with the information that is available and the scarcity of systematic training materials.

The following section gives a brief account of one possible training strategy. Similar strategies are presented in more detail by Billie Bentzen in Foundations of Orientation and Mobility and by Dr. Edward Berla' in the Tactile Graphics Guidebook.

An Approach to Training

Maps and diagrams are abstract two-dimensional representations of real environments and real objects. It should not be assumed that blind children immediately realize the correspondence between real objects or environments and their graphic representations. Training should begin at this most basic level by simultaneously presenting familiar three-dimensional shapes (circle, square, triangle) and objects (coins, spoon, pencil) with their raised image representations. An intermediate step of actually thermoforming the object itself might help the student make the transition to the more abstract two-dimensional raised line drawing. Initially, there should be a one to one correspondence between the object and two-dimensional graphic, only later giving way to transformations of scale. Until these concepts are grasped it is not advisable to use representations of objects that cannot be easily examined tactually (house, bridge, insect). Pairing three-dimensional models of such objects with their two-dimensional representations might be helpful at this stage.

After the student has acquired the idea that objects can be represented abstractly on a tactile display, the next step is to show that the spatial relationships between objects can also be represented. To accomplish this, several small familiar objects can be placed on a work surface. The spatial relationships between the objects can then be described to the student while he examines them tactually. The same arrangement is then presented in a raised line drawing. A variety of arrangements should be used to give the student practice in recognizing and describing a number of different spatial relationships such as left, right, far, near, between, next to, above, and below. Subsequent activities of a similar nature might involve the use of braille letters (e.g., the first letter of the object's name) and abstract graphic symbols to show the student that objects can also be represented by tactile shapes which bear little or no resemblance to the actual objects. The importance of teaching students how to use a key becomes apparent at this point.

As with diagrams of objects, the student's first map should be a representation of something with which the student is thoroughly familiar, such as the classroom. Once again, the construction and examination of three-dimensional models may help facilitate the transition to two-dimensional representation. Such representations should initially contain very few symbols, with increasing detail added as training proceeds. The maps can then be expanded to include other areas in that environment. Throughout all of these activities, the student should be performing a variety of mobility tasks using the maps. There are several aids available for use in these types of activities. For beginning level instruction in map concepts, APH's Introduction to Map Study I has proved useful. For slightly more advanced work, one could use the Chang Tactual Diagram Kit (APH). This kit of map making parts also contains instructional materials. Both of these aids, however, use three-dimensionals. For raised line representations, one could use either of the graphics kits mentioned previously.

For facilitating the understanding of geographical maps, APH has several useful aids. The APH Landform Models consists of a set of 10 three-dimensional tactual maps which illustrate 40 distinct geographical concepts. A recorded program called Doobie the Brain provides instruction in these concepts, and leads nicely into the more advanced study of geographical maps covered by the APH Simplified Continental Relief Map--Cassette Program. These modules include three-dimensional scaled-down models of all the major continents and recorded instructional materials. Finally, the transition to two-dimensional map representations is aided by APH's Introduction to Map Study II, which utilizes a set of hybrid models (i.e., which contain both two-dimensional and three-dimensional representations) to introduce the symbology--points, lines, and areal patterns--used in two dimensional graphics. The extent to which such materials help a blind student understand two-dimensional raised-line maps has not, however, been formally studied. As a matter of fact, this entire synopsis of an approach to training is just that, an approach. To my knowledge no research studies have been conducted which attempt to examine the effects of a long range, systematic, comprehensive training program on the development of map reading skills and concepts. Such studies would contribute greatly to our understanding of the problems involved in learning how to interpret tangible displays.

Graphs: A Neglected Area

There have at least been some efforts devoted to the training of map interpretation. The same cannot be said for graphs, despite the fact that they represent a significant proportion of the graphics that appear in print. Their importance as a communications tool is attested to by the frequency with which they appear in textbooks and other educational media, in such diverse subject areas as mathematics, social studies, physical sciences, biological sciences, and business. They are increasingly encountered in newspapers and magazines. Graph literacy is expected of any educated person and is in fact tested in standardized educational measures such as the Stanford Achievement Test, the California Achievement Tests, the Scholastic Aptitude Test (SAT), and the American College Testing Program (ACT). The college-bound or career-bound blind person will be particularly handicapped by an inability to read graphs.

To bridge this gap in a blind person's education, a project was undertaken at APH to develop a training program in tangible graph interpretation. The remainder of this article focuses on the development and field testing of this now completed program, called Tangible Graphs. (Development of this program was made possible by a grant from the U.S. Department of Education; Grant number G008001878; Project number 023CH10324).

In developing this program the following activities were carried out sequentially: (a) an identification of fundamental graph reading skills, concepts, and operations, (b) the incorporation of these skills, concepts, and operations into a graph test, (c) the development of an instructional program, (d) field evaluation, and (e) revision and production.

The first activity laid the foundation for the entire project. Skills, concepts, and operations fundamental to the graph reading process were derived by rigourously analyzing the explicit (what information is being sought) and implicit (what skills, concepts, and operations are assumed) tasks required by the graphs which appear in textbooks, graph instructional programs for the sighted, and standardized academic tests. The types of graphs commonly used and the grade level at which each type is typically encountered were also identified during this search and analysis phase of the project.

Forty textbooks in the areas of mathematics, social studies, science, and business from grades 2-12 were scrutinized. The graph content of two standardized tests was also analyzed. In addition, 14 print graph instructional programs were identified and their contents examined in detail. These task analyses resulted in the identification of approximately 70 skills, concepts, and operations that are needed to interpret the information contained in four main types of graphs: pictographs, bar graphs, line graphs, and circle graphs.

A criterion-referenced, multiple-choice test was then developed for assessing a student's attainment of these skills and concepts. The test had a twofold purpose: (a) to serve as a diagnostic instrument for determining a student's level of mastery prior to entry into the program (where to start) and subsequent to instruction (further emphasis, remediation) and (b) to serve as an assessment instrument in the program evaluation phase of the project.

In constructing the instructional text itself, my objective was to develop the fundamental graph reading skills and concepts in a systematic, logical sequence of increasing difficulty or complexity. The approach taken was basically an amalgamation of two skills training techniques, the part-continuous method and the linear programming method. In the part-continuous approach to training, the parts making up a skill are presented to the learner one at a time. As each new part is presented, it is practiced in conjunction with previously learned parts until the entire skill is built up. The linear programming method follows a similar strategy and further specifies that the sequential steps used in developing a skill or concept be small in size. This is to insure that each step is understood by the learner, thus avoiding frustration and providing positive reinforcement. Such systematic approaches were found to be lacking in existing graph instructional programs for the sighted. These programs typically used large or extremely erratic step sizes and in many cases did not even attempt to develop a logical progression of complexity either within graph types (for example, presenting a multiple line graph prior to a single line graph) or between graph types (for example, presenting line graphs prior to bar graphs or pictographs). In addition, all of these programs made assumptions about prior knowledge of various skills and concepts, although these assumptions differed between programs.

Based on the fact that blind students characteristically exhibit poor tactual display-reading skills and generally receive little instruction in graphic interpretation, it was decided that the present program should begin, as it were, at the beginning. Consequently the first part of the program, or approximately 25% of the 164 page text, is devoted to the development of skills and concepts that are prerequisites to the effective interpretation of any tangible graphic display. Thus, the text begins with an examination of points, lines, and areal patterns, the building blocks of all graphic displays. Distinctive features of symbols both within and between these three symbol classes are discussed; perceptual training is given in the form of pair comparison and matching tasks. The symbol sets are presented in both paper and plastic (Brailon) media to acquaint the student with the characteristics of each. Both media are used throughout the program, in approximately equal proportions.

The program then proceeds to a discussion of directional and locational referents, both with respect to the layout of the page itself and the interrelationships of elements appearing on a page. This is followed by training in several tactual-motor skills which have been found to improve one's display-reading proficiency. These include such things as how to systematically scan a display and how to track lines effectively using both index fingers. These skills are practiced on displays of increasing complexity, from lines in isolation to intersecting lines to lines embedded in points and areal patterns. Much of the work is couched in the form of games to elevate student interest. Concepts are then presented which are essential to an understanding of the interrelationships of lines, the most frequently used class of symbols in graphs. These include such concepts as horizontal, vertical, diagonal, parallel, perpendicular, intersecting, longer, and higher. All the above skills and concepts are covered in Volume 1 of the program. Since they are in fact essential to the interpretation of any type of graphic display, this volume should also prove useful in the introductory stage of any tangible graphics training program, including map reading.

The final two volumes of the program focus on concepts more directly related to graphs, beginning with an exposition on number lines. Pictographs are presented next and are then used to develop an understanding of simple bar graphs. After exploring the distinctive features common to all graphs (title, axes, axes labels), the idea that a given location in two dimensional space can be specified by means of a coordinate reference system is introduced. This proceeds from a discussion of rows and columns (layout of desks in classroom; tables) to the layout of streets in a map to the grids used in graphs. Point location exercises follow, again in game form.

Bar graphs are then used to develop an understanding of simple line graphs. The interpretation of increasing and decreasing line trends is particularly emphasized in this section. Following a discussion of circle graphs, the program returns to line graphs to deal with more complex concepts such as slope and the presentation of multiple data curves in a single display. Discussions and exercises in this concluding section of the program focus primarily on the process of comparing two or more data curves.

Throughout the program, an active student role is fostered, not only in examining and interpreting the numerous displays presented in the text, but also in graphing data generated by the student himself. Materials are included to facilitate the graph construction process, and suggestions for relevant activities are included in a Teacher's Guide. This guide, which contains a complete print version of the program, also presents information pertinent to the development of systematic display-reading skills and strategies (for example, a systematic strategy for determining the coordinate values of a graph point using the index fingers of both hands). It has been found that the single most important factor distinguishing effective from ineffective display reading is the use of some type of systematic approach.

The last major phase of the project involved a field evaluation of the program. One group of 30 braille reading students from grades 5-10 was designated an experimental group and given instruction in the graph program. No instruction was given to another group of 30 braille readers in grades 5-10, who thus served as a control against which the efficacy of the instructional program could be determined. Both groups were administered a test of graph skills, concepts, and operations at the beginning and end of the evaluation period. The results of this study indicate that substantial gains in graph reading performance can be achieved with Tangible Graphs in a relatively short amount of time.

The experimental students in grades 5-7 increased their test scores from an average of 48% on the pretest to 80% on the posttest. The experimental students in grades 8-10 increased theirs from 64% to 87%. The scores of the control students in both grade groupings remained essentially unchanged. Furthermore, if one considers only those test questions relating specifically to graph reading skills and concepts, as opposed to more general ones, an additional 9% increase in test scores was realized by the experimental students. While the absolute level of performance was higher for the students in grades 8-10 on both the pretest and posttest, the lack of a significant treatment by grade grouping interaction effect indicated a similar improvement on graph related material for both grade groupings. This was not the case for the test material that was concerned primarily with more general display reading skills and concepts. For this material, in addition to a significant overall effect of instruction, there was also a significant treatment by grade grouping interaction. This latter effect appears to have occurred for several reasons. First, the experimental students in grades 5-7 showed a greater improvement from pretest to posttest than those in grades 8-10 (15% versus 10%). Second, the control students in grades 8-10 improved as much as did their experimental counterparts, while the control students in grades 5-7 showed very little improvement. Why the control students in grades 8-10 improved while those in grades 5-7 did not is not clear. And, finally, it is possible that a ceiling effect was operating to limit the absolute amount of improvement on general display-reading skills and concepts. Those in grades 5-7, starting with a mean score of 70%, had more to learn. It is possible that this ceiling effect also accounts for the significant interaction between treatment and grade level found for the test as a whole. The experimental students in grades 8-10 began the study with considerably more graph reading knowledge than those in grades 5-7 (64% as compared to 48%). Overall, the students in grades 5-7 had more room to improve.

In retrospect, it would have been desirable to observe the effects of the program on an even younger sample of blind children, perhaps from grades 3 and 4. While the relatively high performance of the students in grades 5-7 on general display reading skills and concepts represents an encouraging finding, it limits the evaluation of the program's facilitation in this area. Because of cost considerations and time constraints, it was decided at the beginning of the project that the greatest amount of information could be obtained by concentrating on students who could be reasonably expected to complete the entire program within the time allowed. Since the reading difficulty of the program is approximately at the third grade level, it seems reasonable, however, to assume that younger students could benefit from the program, expecially the first part, which is concerned with general display reading skills and concepts.

Besides the small, but significant, effect of this first part of the program on experimental group scores as a whole, additional evidence for its facilitative effect can be seen in the improvement achieved by individual students. Two experimental students from grades 5-7 are particularly noteworthy in this regard. Beginning the evaluation period with rather low scores of 58% on general display reading skills and concepts, both improved considerably by the posttest, receiving scores of 100% and 96%.

An exceptional amount of improvement was also achieved by several students on graph related skills and concepts. Three students from grades 5-7 improved by 60% on this part of the test. Three others improved by 52%, 55%, and 58%. In grades 8-10, improvements by individuals were not quite as dramatic, the largest increase being 42%. However, as noted previously, the students in this group had less room to improve. Three of the 15 experimental students in grades 8-10 did, in fact, improve to the maximal extent possible, receiving perfect scores on this section of the posttest. Two others received a 95% on the posttest.

Considering both group outcomes and the performances of individual students, it is, therefore, clear that substantial gains in tangible graph reading skills, concepts, and operations can be realized by students receiving appropriate instruction. This is especially significant given the fact that (a) 23% of the students in the experimental group did not complete the program, and (b) the program was only taught for an average of 1 1/2 hours per week over a 10-week period. These limitations were largely due to time constraints. Several teachers suggested that two semesters (rather than one) would be more realistic for a thorough study of the program materials. In particular, they indicated the need for more time to do justice to the participatory exercises.

In addition to the performance data collected on each student, subjective feedback on both the program itself and the graph test was obtained from all of the teachers in the experimental group. The teachers in the control group provided feedback only on the graph test. In general, an extremely favorable response to the content and design of both the program and the graph test was found, indicating a high degree of face validity for both.

In conclusion, it has been my experience that blind students are capable of using tangible graphics and generally enjoy doing so. These points stood out in the field evaluation of Tangible Graphs. Tangible graphic displays provide access to a significant and useful body of knowledge. Failure to provide appropriate training in this area for blind persons further handicaps them in a sighted world. Certainly, we still have much to learn about the complexities of the display-reading process, the design characteristics of readable tactile displays, and effective training approachs and materials. This should not, however, stop us from proceeding. There are sufficient information and materials available for dramatically increasing the graphic literacy of blind persons. It is about time we took this responsibility more seriously.